Effects of Cooling with Simulated Ice on Skin Temperature and Nerve Conduction Velocity

Commercially produced cold packs, which may be refrigerated to simulate ice packs, are preferred by many physiotherapists for cooling treatments. In the experiments described here, the efficiency of cold packs and ice packs was determined by measuring their effects on skin temperature and the conduction velocity of motor nerve fibres. Although the commercially available cold pack did alter the measured physiological variables, ice was found to be the more effective method of cooling superficial and possibly deep tissue.

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Numerous studies on animals and man have investigated the relationship between nerve conduction velocity and temperature. For example, Franz and Iggo (1968) using the cat saphenous nerve, observed the slowing of conduction velocities in large and small axons which accompanied temperature decreases. The human ulnar nerve was used by Lee, Warren and Mason (1978) for their experiments of changes in motor and sensory fibre conduction subsequent to application of an ice pack for twenty minutes.

It was not the purpose of the present study to support the many observations of reduction of nerve conduction velocity with cooling, but rather to attempt to determine the relative effectiveness of three procedures commonly used in clinical practice, namely cooling with re-usable ‘cold packs’ in both dry towelling and damp towelling, and a prepared ice pack in damp towelling.

Commercially available ‘cold packs’, which are refrigerated to simulate ice, may be preferentially used by physiotherapists to cool a patient’s skin or deep tissue. These re-usable cold packs, which are filled with polyvinyl alcohol, appeal to many clinicians because, in comparison with ice, they are a cryotherapeutic modality package available in various sizes with easy handling characteristics. Certainly among some physiotherapists and sports trainers, it has been suggested that commercially available cold packs and a prepared ice pack of about the same size are equally efficient therapeutically. We have attempted to investigate this suggestion by examining whether a commercially available cold pack would cool skin and deep tissue in the same time and to the same extent as an ice pack of the same size. In our experiments, the conduction velocity of the ulnar nerve motor fibres was used as a measure of changes which occurred in the forearm where the ulnar nerve is overlain with muscle and fat (ie ‘deep’ tissue).

Method
Subjects
Twelve females and six males between the ages of 20 and 55 years were used for the investigations. No subject had any history of neurological, muscular or endocrine pathology, nor was undergoing any pharmaceutical therapy which could affect the velocity of conduction in peripheral nerve fibres.

Apparatus
Skin temperature was measured with a Yellow Springs Telethermometer type 42T.

Transcutaneous nerve stimulation was achieved at the elbow through two disposable electromyography (EMG) electrodes, 4 mm in diameter, applied approximately 30 mm apart on the skin above the ulnar nerve trunk proximal to the medial epicondyle. A similar pair of electrodes were positioned at the wrist approximately 20 mm apart along the ulnar nerve trunk adjacent to the tendon of flexor carpi ulnaris. Stimulating current was supplied by a Grass SD9 stimulator. Electromyographic recordings were obtained of abductor digiti minimi through two EMG electrodes located on the muscle belly with an inter-
Electrode distance of 20 mm. Muscle activity was displayed on a Tektronix D13 dual beam storage oscilloscope.

Procedure
The experiments were performed in a quiet well lit room maintained at 20°C. Each subject was required to attend three experimental sessions of about one hour’s duration, spaced one week part. Temperature stabilization of the subjects’ upper limbs was achieved by exposure of the area and seating the patient comfortably with arms supported in a standard position for 15 minutes prior to the commencement of each experiment.

During each experimental session the conduction velocity of a subject’s ulnar nerve and forearm skin temperature were recorded before, during and after the application of a single cryotherapeutic modality to the forearm.

Subjects were seated comfortably during each session, the subject’s arm resting on a pillow placed on the lap. Electrode positions and the location of the temperature probe were marked with a dye so that the same locations could be used for each investigation.

During separate experimental sessions one of the three different cryotherapeutic modalities was applied to each subject’s right forearm. An 80 mm x 280 mm towelling bag was filled with crushed ice or a closely fitting commercially available cold pack (Hydrocollator Colpac 80 mm x 280 mm, Chattanooga Pharmacal Co., U.S.A.). For the latter, in one series of experiments the towelling bag was dry and in the other series the Colpac was inserted into the towelling bag which had been dampened with iced water.

Both the ice and the Colpac were refrigerated to -4°C before being placed in the bag. The pack was then firmly strapped to the subject’s upper forearm for twenty minutes in a position such that a large area of skin was contacted. Skin temperatures and ulnar nerve conduction velocities were recorded at five minute intervals during three periods of twenty minutes each: twenty minutes before the cryotherapeutic modality was applied; during the twenty minutes of cooling of the skin; and for at least fifteen minutes after removal of the cold pack.

Calculation of nerve conduction velocity
The conduction velocity of the ulnar nerve fibres was calculated in a standard manner (Smorro and Basmajian 1979). Electromyographic activity of the muscle contraction evoked by electrical stimulation of the ulnar nerve at the elbow and wrist was displayed on the oscilloscope permitting measurement of the latency of the evoked response. Nerve conduction velocity was then calculated by dividing the separation of the stimulating points by the difference in the latencies of the evoked EMG.

\[ \text{Ulnar nerve conduction velocity (metres second}^{-1}) = \frac{\text{distance between wrist cathode and elbow cathode (metres)}}{\text{EMG latency (elbow stimulation)} - \text{EMG latency (wrist stimulation)}} \]

Results
When a Colpac was used to cool the forearm skin, rapid decreases in skin temperature were noted as the cooling progressed. These depressions of skin temperature were accompanied by decreases in the conduction velocity of the motor fibres of the ulnar nerve. After twenty minutes application of a Colpac in a dry towelling pack the mean temperature of the forearm skin was 12.5°C (Standard Deviation 2.1). This temperature was not significantly different from that obtained with a wet towelling pack (Table 1). At the same time, the mean conduction velocity for ulnar nerve fibres was measured as 48.2 metres second^-1 (mean, Figure 1). This represents approximately 10 per cent reduction of the conduction velocity of the nerve fibres. After removal of the Colpac, skin warming was at first rapid but then

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Mean Temperature °C dry towel</th>
<th>'Colpac' wet towel</th>
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</thead>
<tbody>
<tr>
<td>Before treatment</td>
<td>30.0 (1.5)</td>
<td>30.2 (1.6)</td>
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<tr>
<td>After start of treatment 5</td>
<td>9.2 (2.6)</td>
<td>17.6 (3.9)</td>
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<tr>
<td>10</td>
<td>7.1 (1.7)</td>
<td>15.2 (2.9)</td>
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<td>15</td>
<td>5.6 (1.5)</td>
<td>13.8 (2.6)</td>
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<td>20</td>
<td>4.4 (1.2)</td>
<td>12.5 (2.1)</td>
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<tr>
<td>25(5)**</td>
<td>15.1 (2.1)</td>
<td>18.8 (2.2)</td>
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<tr>
<td>30(10)</td>
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<tr>
<td>40(20)</td>
<td>22.5 (1.8)</td>
<td>23.4 (1.4)</td>
</tr>
</tbody>
</table>

* The standard deviation for each mean is shown in parentheses (1).
** Values in parentheses indicate the time after removal of the ice or 'Colpac'.

Effects of Cooling with Simulated Ice

![Graph showing mean nerve conduction velocity over time](image)

**Figure 1**: The mean nerve conduction velocities are plotted against the time from application of each cooling medium. The open triangle on the abscissa indicates the time of removal of the cooling medium. Closed circles indicate values for a 'Colpac' in a dry towel, closed triangles for a 'Colpac' in a damp towel and squares indicate values obtained for ice.

The skin temperature and conduction velocity of nerve fibres were brought about by cooling the skin with an ice pack. After twenty minutes the mean temperature of the skin of the forearm was reduced to 4.4°C (Standard deviation 1.2, see Table 1). This temperature was significantly different (p<0.05 t-test) from the temperatures observed when the skin was cooled for the same period of time with a Colpac in a wet or dry towelling bag. Moreover at this temperature the slowest conduction velocity of the ulnar nerve fibres was recorded (Figure 1: 43.8 metres second⁻¹) although the change was not significantly different.

Removal of the ice pack was again followed by rapid elevation of skin temperature. The conduction velocity of the nerve fibres increased during this period, but twenty minutes after the removal of the ice pack the mean temperature of the forearm skin was still 7.5°C below the pre-treatment temperature. The conduction velocity of the ulnar nerve fibres (Figure 1: 47.1 metres second⁻¹) was then approximately 12 per cent below the pre-treatment value.

**Discussion and Conclusions**

Several phases are observable in the temperature changes which occur when the skin is cooled and then allowed to regain its normal temperature. Application of a cooling medium at first produces a rapid decrease in skin temperature. A slower decline in the temperature of the skin then occurs as application of the cooling medium continues. Removal of the cold medium permits a rapid increase of the skin temperature, but warming slows as the normal skin temperature is approached (Lewis and Clayfield 1981). These changes were noted in our experiments when either ice or a commercially available cooling medium were used. The observed changes were more dramatic when ice was used, since skin temperature was decreased a further 7.9°C (mean) when this medium was applied. In addition, when applied for the same time, the maximum cooling of the skin obtained with ice was significantly greater (p<0.05) than the cooling achieved by application of a Colpac.

Maintained skin cooling may also decrease the temperature of any underlying muscles (Lowdon and Moore 1977) and the conduction velocity of underlying nerve fibres (Johnson and Olsen 1960). In peripheral nerves, the conduction velocity of all myelinated fibre groups falls gradually with decreasing temperature, until conduction is blocked. The relationship between conduction velocity and temperature is roughly linear (Franz and Iggo 1968).
Effects of Cooling with Simulated Ice

![Graph showing temperature reduction over time](image)

**Figure 2:** The mean decrease in temperature is graphed against the time from application of each cooling medium. Symbols used are the same as those shown in Figure 1.

Our results indicate that at all measured skin temperatures, the mean conduction velocity of motor fibres in the ulnar nerve was decreased more when the skin was cooled by ice. The decrease, however, was not significantly different (p>0.05 t-test) from that which occurred when a Colpac in a damp towelling bag was applied to the skin for the same period of time (Figure 1). It could be proposed therefore, that ice was more effective in cooling the skin, but not more effective than the Colpac in reducing the temperature of deep tissue (in the present study, muscle and fat which overlapped the ulnar nerve in the forearm).

During the course of one series of the experiments the towelling bag used as a container for the Colpac was dry. This procedure appeared to produce greater cooling of the skin, but not significantly more reduction of the nerve conduction velocity, than occurred when a damp towelling bag was used (Figure 1). The reasons for this require investigation.

Whatever the case, our results tend to support ice as the most efficient method for producing a temperature decrease of skin and perhaps of underlying tissue.

**References**


